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Motor tests and experiments in light.

Bennett Mattingly Brigman 1881-1938
University of Louisville

"MOTOR TESTS AND EXPERIMENTS IN LIGHT"

A THESIS

SUBMITTED TO THE FACULTY

of the

COLLEGE OF ARTS AND SCIENCES

of the

UNIVERSITY OF LOUISVILLE

through

PROFESSOR WARWICK M. ANDERSON

IN CANDIDACY FOR THE DEGREE

of

"MASTER OF SCIENCE"

by

BENNETT MATTINGLY BRIGMAN

1912

"MOTOR TESTS AND EXPERIMENTS IN LIGHT"

THESIS

of

BENNETT MATTINGLY BRIGMAN

candidate

for

DEGREE

"Master of Science"

University of Louisville

Louisville, Ky.

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To the Faculty of the
Acedemic Department,
University of Louisville,

Louisville,Ky.

Gentlemen:-

Herewith,I am tendering you the results of my collegiate year's work in the Physical and Electrical Laboratories,as my Thesis for the Degree of Master of Science.

My work in the University,under Mr.Anderson,has never reached the point of monotony or drudgery,but has been that of pleasure and accomplishment.The time has been entirely too short is my one regret.

I wish to take this opportunity of expressing my thanks and appreciation to Mr.Anderson and Dr.Patterson for their kindness and attention and the many courtesies extended to me throughout the year.

Yours very respectfully,

B.M. Brigman

Physics

Books of Reference.

Carharts College Physics.

Ganots Physics.

Reed and Guthe Physical Measurments.

Mann's Manual of Advanced Optics.

Ames and Bliss Manual of Experiments.

Optics--Ency.Brit.(Lord Rayleigh)

Determination of the Angle of a Prism.

This experiment was performed by the use of a Spectrometer using the customary methods of measurements usually adopted for this work.

Method "A" The telescope having a Gaussian eyepiece attachment, the telescope's cross-hairs are illuminated and reflected upon the two plane faces of a prism in succession. The angle through which thetelescope is turned between the first and second face equals 180° - A, where A is the angle of the prism.

Method "B" The Collimator so placed that the slit is illuminated by a flame it falls upon both faces, being divided by the edge of the prism. Each of these sections is reflected from the corresponding face and the angle of reflection measured by the telescope. As the telescope turns from one beam to the other it moves through an angle of 360° - 2A.

Method "C" Place the Collimator so that the light is reflected from one face only of the prism, and focus the telescope upon the reflected beam. Keeping the collimator and telescope fixed, turn the platform upon which rests the prism, until the second face of the prism reflects the light from the collimator through the telescope. The angle through which the prism has been turned is 180° ± A, depending upon the direction the prism has been turned.

Determination of
Angle of Minimum Deviation
and
Index of Refraction.

The angle of deviation is defined as being the angle by which the direction of the emerging waves of light differs from that of the incident ones, when the planes fall upon a prism. For a definite prism and for a definite ray of light there is a certain angle of incidence for which the deviation is a minimum, this angle is the Angle of Minimum Deviation, for the given prism and light.

The method pursued in determining this angle is to place the prism upon the table of a Spectrometer and arrange a Sodium flame so as to illuminate the slit of the Collimator that the light from it will fall upon one face of the prism and be refracted into it and out the other into the Telescope. Make the angle of incidence as great as possible and then decrease the angle of incidence by steps until it is noticed that there is a certain angle that any further decrease in the angle will make the angle of deviation reverse the direction of its change. A reading of the verniers is made of this result. The telescope is now turned so as to be in direct line with the collimator as shown by the slit of the collimator coinciding with the cross-hairs of the telescope, and this reading taken.

Angle	Telescope made with refracted image,----------	214°00"
Angle	Telescope made with the Collimator------------	160°22"
	Angle of Minimum deviation, or, "D" =	53°38"

Since the ratio of the sines of the angles of incidence and refraction for the same two media, is called the Index of Refraction for the light used, and denoting these angles by "i" and "r," we have-

The deviation at the first surface of the prism is, "i"-"r," at the second surface, "i'"-"r'", the total deviation is, D = "i"-"r" + "i'" - "r'" = "i"+"i'"-(r+r'). The angle of the prism A equals the sum of the two interior angles r and r', therefore A=2r.

$$D = 2i - 2r = 2i - A$$

or, $i = \frac{A+D}{2}$ therefore the index of refraction-μ may be calculated from the formula,

$$\mu = \frac{\text{Sin } 1/2(A+D)}{\text{Sin } 1/2 \text{ A}}$$

Angle A = 60°00"
Min. Dev = ∠ D = 53°38
∠A + ∠D = 113°38"
½ ∠A + ∠D = 56°49'

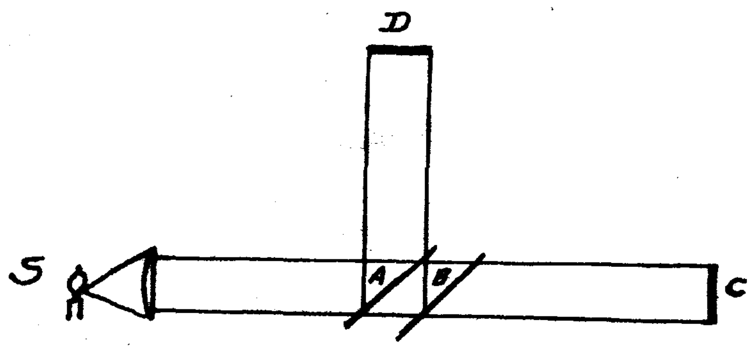
Log Sin ½ A+D = 9.922686
" " ½ A = 9.698970
Log μ = .223716
μ = 1.6713

The Michelson Interferometer.

The essential parts of the Michelson Interferometer consist of glass plates arranged as indicated in the sketch.
Let A, B, C, D, represent the projections of the four plates on a plane perpendicular to their surfaces. Light from a source S falls upon the plate A at an angle of incidence of approximately 45°. C and D are two plane mirrors, coated on the front surfaces with a thick coat of silver, and so adjusted as to reflect the light incident upon them, back over nearly the same path. These two reflected beams meet again on the rear surface of the plate A in a condition suitable to the production of interference bands. The plate B is inserted to make the two paths optically identical.
The plate D is a part of a moving mechanism whereby measurments can be made. The one in use for the results given, gives direct readings. Sodium light was used and its wave length was measured as follows-

Fringes		MM
100		5900×10^{-7}
100		5900×10^{-7}
100		5800×10^{-7}
100		5886×10^{-7}
	Mean =	5891×10^{-7}

The correct value is given as- 5896×10^{-7}



Electrical
Books of Reference.

Franklin & Estys Elements of Electrical Engineering.

Franklin & Estys Dynamo Laboratory Manual.

Wieners Dynamo-Electric Machines.

Sheldons Dynamo -Electric Machines.

I. C. S. Electrical Engineering.

A. S. C. Electrical Engineering.

Kents Mechanical Eng'rs Handbook.

Thompsons Elements of Electricity.

Swoopes Practical ElCctricity.

Jacksons Elements of Electricity.

Manufacturers Bulletins as folloes-

Westinghouse Elect. Mfg.Co.

General Electric Co.

Fairbanks,Morse & Co.

Electrical Laboratory.
Direct Current.

The equipment for this laboratory work consisted of the following apparatus:

1--Horizontal Gas Engine, 15 H. P., 300 R.P.M. Flywheels, 66" x 6"" Auxilliary flywheel 34" x 9".

1--Compound wound Generator, belt driven. Thpe T.R. Rated at 110 volts no load; 115 volts full load. Adjusted for 1150 R.P.M.

1--Shunt wound Motor, 10 H.P. 115 volts, 76.5 amperes 1100 R.P.M. full load.

1--Series wound Meter, 10 H.P. 115 volts, 76.5 amperes 850 R.P.M. full load. Rated as Intermitting.

1-- Compound wound Motor. 10 H.P. 115 volts, 76.5 ampere 1100 R.P.M. full load.

1-- One panel Switch board, equipped with Ammeter, Voltmeter, Rheostat, three knife switches with fuzes. Power delivered through Main switch to Bus bar in rear of board. Circuits for motors and lights to Bus bar.
The Compound and Shunt motors connected through Cutler & Hammer Starting Boxes.
Series motor connected with F,M & Co Controller (with plate resistance) and Automatic low amperage Cut-out.

1--Jack shaft with three pulleys for motor drives.

In addition to the above the laboratory is equipped with all the necessary Measuring Instruments.

The equipment of Machines, Switch board and Boxes were furnished by Fairbanks, Morse & Co.

Field Resistances.

In determining the resistance of the Field coils of the machines, the coils were connected in Series with an Ammeter and Water Rheostat. The voltage was taken across the terminals of the coils. This method is known as the Ammeter-Voltmeter method of determining resistances.

Simultaneous readings were made of current and voltage for each change or addition of current.

Calculations were then made by applying Ohm's Law.

In each instance the Coils were allowed to be slightly heated, and the results given are therefore Hot Resistances unless otherwise specified.

Fairbanks-Morse & Co., supplied the results of the tests for Resistance on the machines in use and specify that a fairly accurate result for obtaining a Hot Resistance of these machines would be to add 20% to the Cold Resistance.

Armature Resistance

The same methods were used in determining the Resistance of the Armature s. In each case unless otherwise specified Armature resistance includes, brushes, brush holders and leads

All resistances are Hot resistances unless otherwise noted.

20% additional allowed in determining the Hot Resistance from that of the Cold resistance, same as in Fields.

Field Resistances-Compound Machine.

Shunt Coils.(Cold)

Amps.	Volts.
1.1	39.0
2.1	73.0
3.0	101.0
3.5	119.0

Average- 34.4 Ohms.

F-M & Co. results give- 34.0 Ohms.

Series Coils (cold)

14.5	.15
23.0	.275
35.0	.45
43.0	.55
50.5	.65

Average- .011 Ohms.

F-M & Co results give- .01 Ohms.

Armature Resistance, Series Machine.

Amperes	Volts.
18	3.0
23	3.75
29	4.50
36	5.50
46.5	6.75
80	11.00

Average. .1534 ohms.

Revised test. 4/1/12.

35	5.0
44	6.5
71	10.0

Average. .143 Ohms.

For Cold Resistance, F-M & Co. give .087Ohms.
20% additional gives .104 Ohms

On determining the Resistance of a separate Armature Coil (cold) the following average result was obtained- .090, which compares with the result of the manufacturers.

Field Resistance, Series Machine.

Amps.	Volts.
1.5	.15
3.0	.25
6.0	.50
9.0	.75
14.0	1.20
16.5	1.40
17.5	1.50
20.0	1.75
23.0	1.95
24.0	2.00
30.0	2.50
38.0	3.10
42.0	3.50
46.0	3.75
55.0	4.60

Average.- .0834 Ohms.

Revised 4/15/12.

27.0	2.50
35.0	3.0
75.0	6.00

Average. .085 Ohms.

F-M & Co. results, (cold) gives- .068
20% additional for Hot Res. gives- .081 Ohms.

Armature Resistance-Shunt Machine.

Amps.	Volts.
3.0	35.0
5.0	50.0
6.0	64.0
8.0	88.0

Average- .092 Ohms.

F-M & Co results,(cold) .054 Ohms.
20% additional gives- .064 "

Field Resistance

Average results- 40.94 Ohms.

F-M & Co results (cold) 39.00 Ohms.

Shifting Brushes.--Shunt Machine.

Loaded

R.P.M.	Brush positions.
994	Normal
990	1/2" from Normal
982	Neutral
996	Max.positions

Zero Load.

1000	Normal
960	1/2" from normal
860	Neutral
1000	Max.positions.

By shifting the brushes forward or backward with zero load the speed increased.
When brushes were placed in the Neutral plane, the speed was decreased.
When brushes were shifted with load excessive sparking was caused in each instance.

Determination of Magnetic Leakage of Shunt Machine.

A number of turns of fine wire was wound around one of the Field coils so as to surround the whole of the flux of this pole; the same number of turns of wire was wound lengthwise about the Armature so as to enclose all of the flux that passes through the Armature from the filed.

The terminals of each of these coils were attached in turn to a low reading Voltmeter.

The Field winding of the machine was connected through a water Rheostat with the switch of the supply mains.

Current was sent through the Fields and the throw of the Voltmeter was observed upon the breaking of the circuit through the fields by means of the switch for each coil.

Current was sent through the fields at three different voltages, namely, 50 volts, 100 volts and 150 volts, and the throw of the voltmeter recorded for each coil.

The Coefficient of Magnetic Leakage is defined by the equation,

$$\nu = \frac{\Phi_c}{\Phi_a}$$

in which, ν represents the the coefficient , Φ_c the total mag. flux in the field and Φ_a is the portion of this flux that passes through the Armature.
The Coefficient is always greater than unity and varies from 1.1 to 1.5 in multipolar machines.

Throw for Field Coils	Field Current volts.	Throw for Arm. Coil	Coefficient.
.55	50	.35	1.28
.90	100	.70	1.28
1.25	150	.90	1.38

Magnetic Leakage is caused by the lines of force taking a shorter path through the air gap between the pole faces and Armature.
The number of lines choosing paths through the gap will decrease as the permeability of the iron circuit increases.
The Armature core varies in permeability under varying conditions of load. As the load increases, the reluctance of the magnetic circuit increases, and therefore, increases the magnetic loss by leakage.
The Coefficient of Magnetic Leakage is different therefore for different loads.

Magnetization Curve
Series Machine.

Field Amp.	Ex't Volts	Ex't Amps.
1	3	2.5
3	7	6.5
4	9.5	9.
6	12.	12.5
8	16	17.
9	18	19.5
10	20	21.
11	21	22.5
12	23	25
12.5	24	27
13	25.5	29
14	27.5	31
15	29	33
15.5	30	35
16	31	36.5
17	32	38
19	37	45
22	40	50
24	43	55
26.5	46	60
28.5	48	63.5
31	51	69
33	53	73
35	55	77.5
37	56	80
40	58	85
42.5	60	88
43.5	77	
47.5	80	
51	83	
54	86	
56.5	87	
58.5	88	
62	91	
75	97	
81	99	
85	101	
93	104	


MAGNETIZATION CURVE
SERIES MACHINE
VOLTS
AMPERES
GOODYEAR-MARSHALL PUBLISHING CO., CEDAR RAPIDS, IOWA.

Characteristic Curves.

The External Characteristic Curve of a machine is a graphical representation of the behavior of the machine during operation. This curve bears the same relation to an Electrical machine as the Indicator diagram bears to a Steam Engine.

To find the External Characteristic Curve of a Generat the machine is driven at a constant speed and simultaneous readings of voltage across the generator terminals and current delivered to a receiving circuit are taken. The receiving circuit should have resistance by which the current can be decreased in steps until the machine is loaded.

To determine this Curve for a motor it is necessary to drive the machine from a constant voltage supply main and to have a suitable Rheostat in series with the machine.
The power should be absorbed by a brake and the same readings observed as in the case of a generator.

The Curve is plotted by representing the various current readings as abscissas and thecorresponding voltages as ordinates.

External Characteristic of Series Generator.

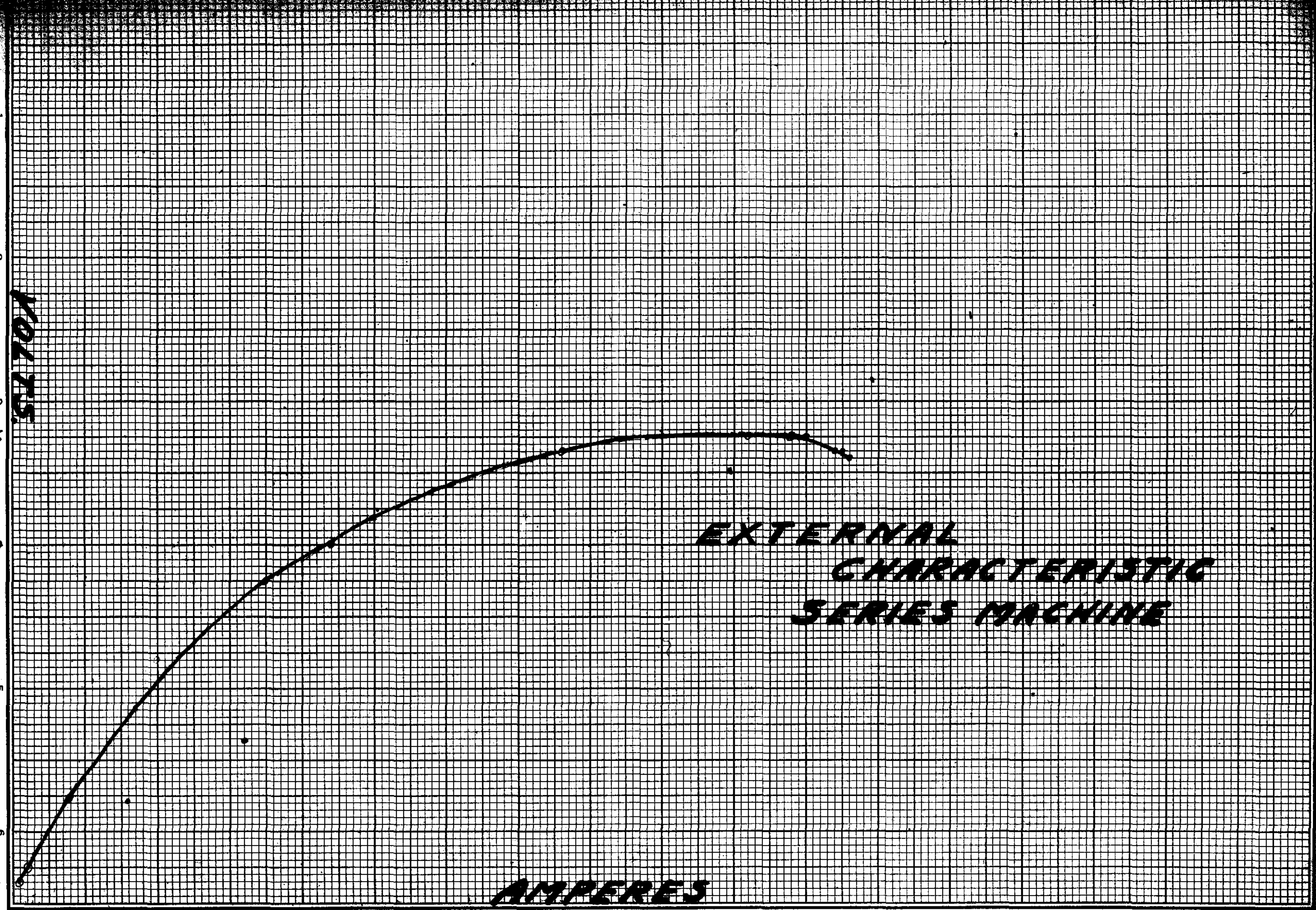
The machine was driven at a constant speed and simultaneous readings were taken of voltage across the terminals and of the current delivered to a receiving circuit in the form of a water Rheostat.The resistance of of this circuit was decreased in steps until the machine was loaded.

Difficulty was experienced in making the machine build up until the machine was short-circuited temporiarily.

The machine was loaded until magnetic saturation took place to such an extent as to make the electromotive force decrease as the current increased.

External Characteristic
Series Machine.

Volts	Amperes
3	1.0
5	2.0
15	8.0
45	38.0
50	44.0
54	55.0
54	76.0
65	102.0
65	108.0
65	110.0
63	114.0
63	115.0
62	116.0



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Characteristic of Compound Generator.

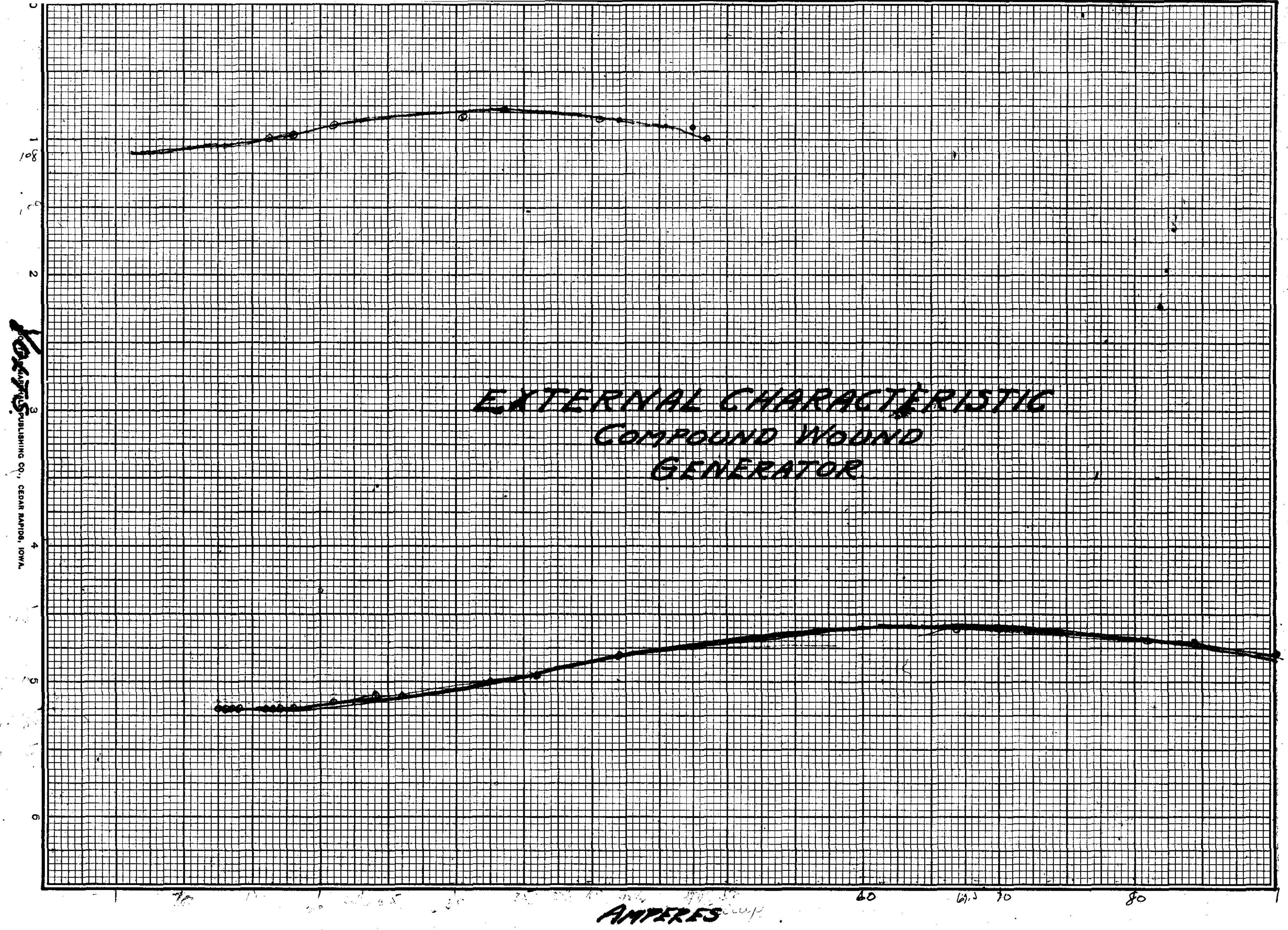
The machine was driven at a constant speed, and zero load. The voltage was adjusted by means of the shunt field Rheostat.

The current out-put was absorbed by a water Rheostat and simultaneous readings taken for voltage and current.

The machine was found to be over-compounded 5 per.cent.

External Characteristic
Compound Wound Generator.

Volts	Amperes
108	12.5
108	13.0
108	13.5
108	14.0
108	16.0
108	16.5
108	17.0
108	18.0
108.5	21.0
109	24.0
109	26.5
110	32.5
110.5	36.0
112	42.0
113	61.5
114	67.0
114	67.0
113	81.0
113	84.0
112	91.0
112	100.0
110	112.0


EXTERNAL CHARACTERISTIC
COMPOUND WOUND
GENERATOR
VOLTS.
AMPERES
1
2
3
4
5
6
40
60
70
80

Characteristic of Shunt Dynamo.

The machine was driven at constant speed, and the terminals were were connected through a water Rheostat with an Ammeter ciruit and a Voltmeter across the terminals.

Simultaneous readings were taken of terminal voltage and of current for each increasing value of current. Speed was adjusted in each case.

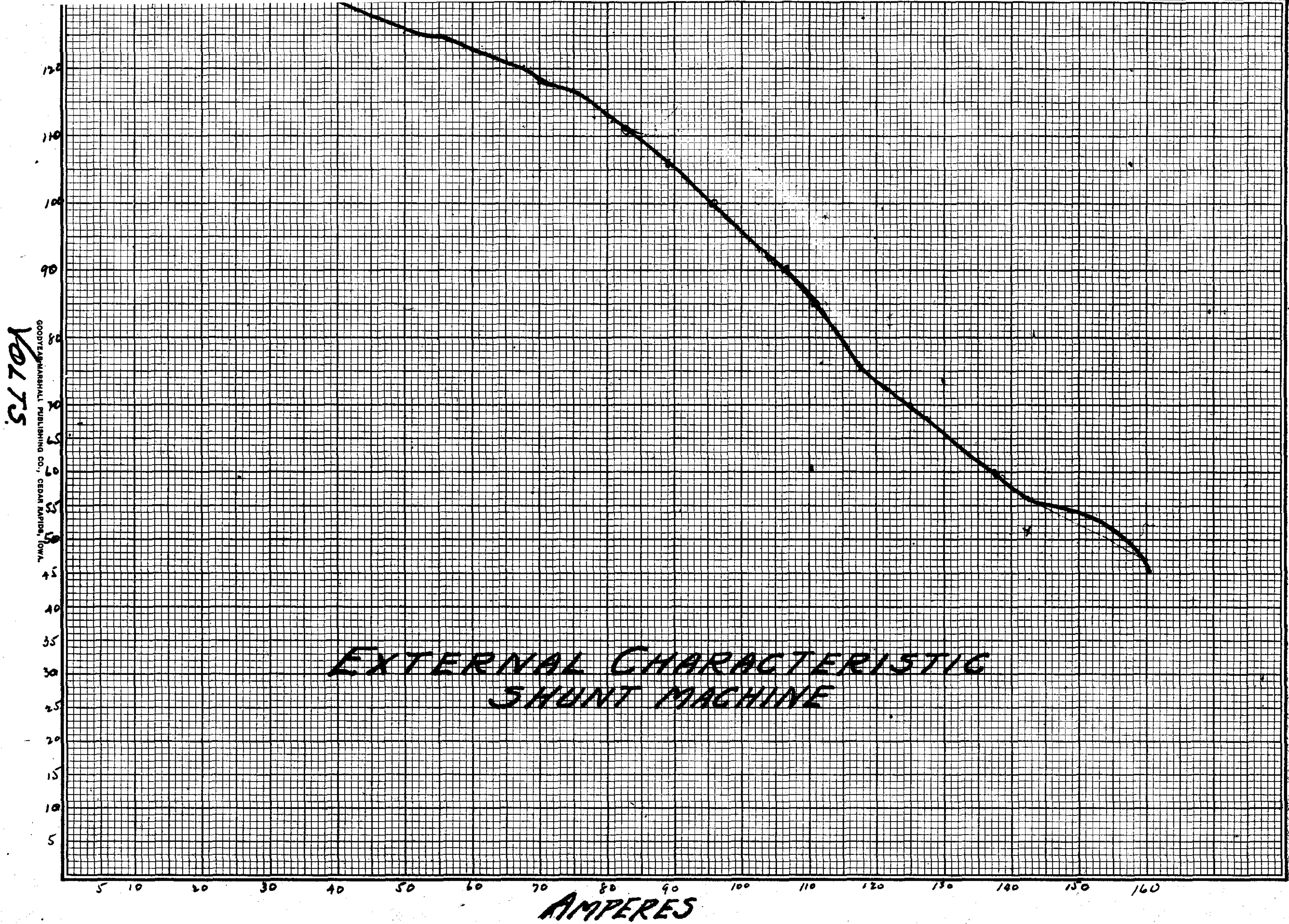
The curve was plotted with voltage as the the ordinates and current as the abscissaes.

In shunt machines it is noticed that the characteriotic curve droops suddenly when the external current reaches a large value and after which both the current and the voltage curve back towards the origin of coordinates. This is caused by the excessive demagnetizing action of the armature current overpowering the field excitation and making the terminal voltage and current fall in value.

External

Characteristic of Shunt Machine.

Volts	Amperes
142	12.5
139	15.0
137	17.5
136	20.0
135	25.0
134	27.5
133	32.5
132	35.0
131	37.0
130	40.0
129	42.5
128	45.0
127	47.5
125	52.5
124	57.5
123	60.0
122	62,5
121	65.0
120	67.5
118	70.0
117	75.0
115	77.5
113	80.0
111	82.5
106	84.0
100	96.0
95	101.0
90	106.0
85	111.0
80	115.0
75	117.5
70	125.0
68	127.5
60	137.5
56	142.5
54	150.0
52	155.0
47	160.0


EXTERNAL CHARACTERISTIC
SHUNT MACHINE
VOLTS
AMPERES
5
10
15
20
25
30
35
40
45
50
55
60
65
70
80
90
100
110
120
130
140
150
160
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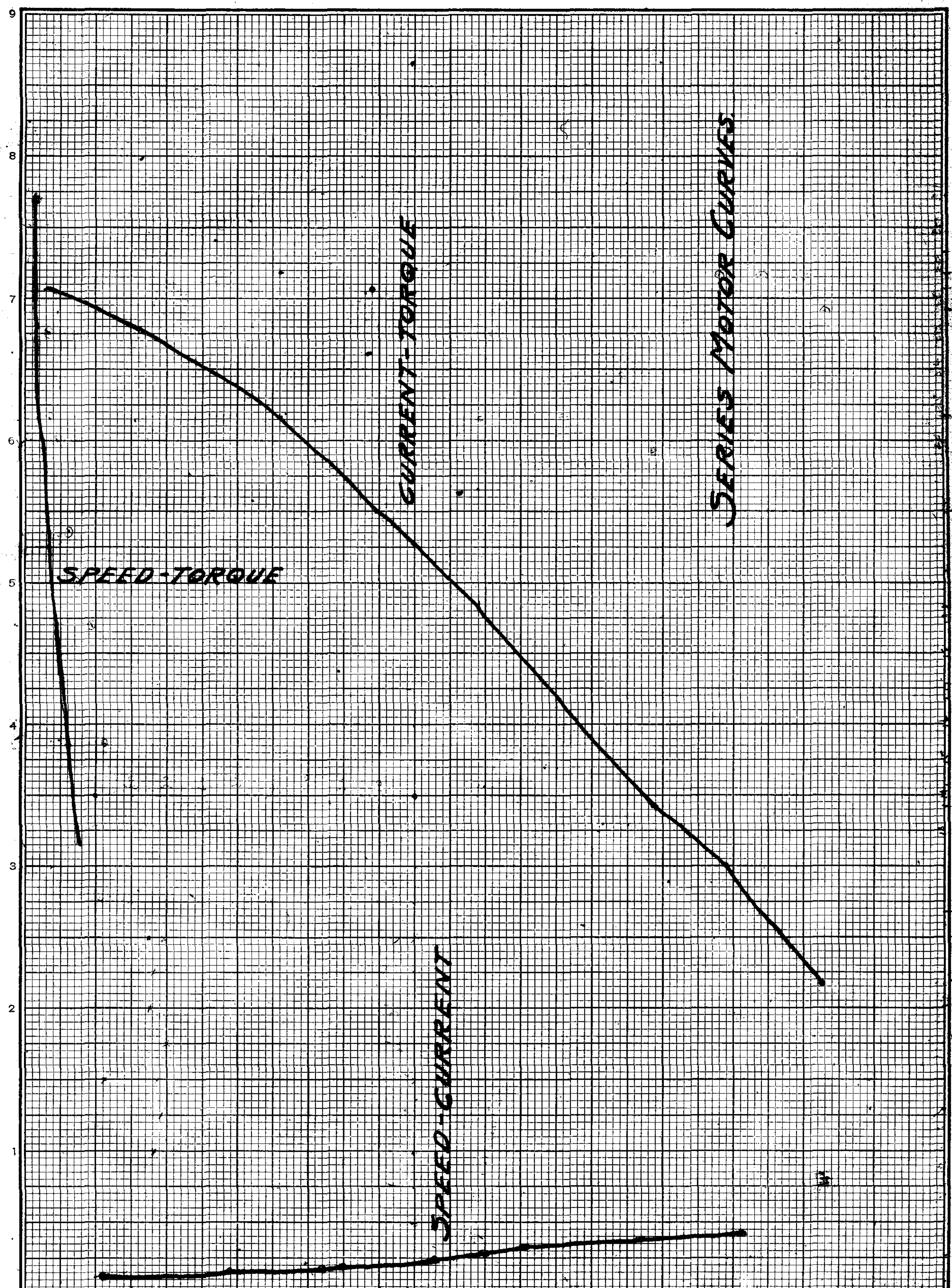
Series Motor Tests.

Volts.	Amps.	Speed	Pull	Torque.	B.H.P.	E.H.P.	Com. Eff.	True Eff.
114	26	1560	2.00	10.50	3.14	3.98	78.8	73.7
114	32	1356	3.00	15.75	4.06	4.89	83.0	76.7
114	36	1240	3.50	18.37	4.34	5.50	78.9	71.8
114	41	1196	4.75	24.93	6.04	6.22	97.1x	33.4x
114	50	1070	6.25	32.81	6.72	7.64	87.9	71.1
114	58	1000	7.50	39.37	7.47	8.72	85.6	74.5
114	66	940	9.25	48.56	8.68	10.00	86.8	74.9
114	74	764	10.75	56.43	8.20	11.30	72.5	58.1
100	85	630	14.50	76.12	9.12	11.30	80.7	61.9

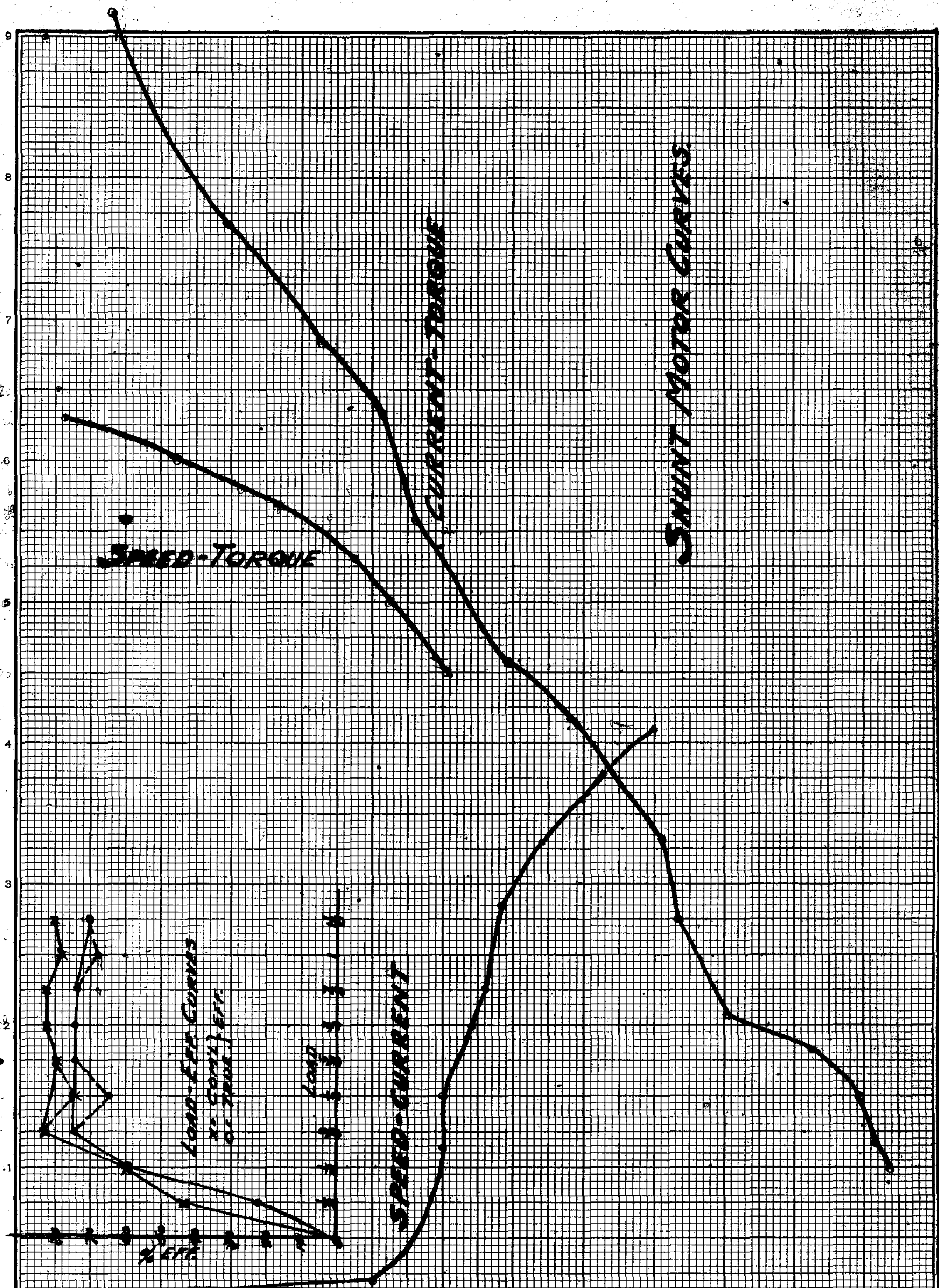
Motor was supplied from constant voltage mains.Power was absorbed by a Proney brake and simultaneous readings were taken ~~of~~,voltage,current,speed and pull of brake beam. It is quite evident that an error of some sort in these readings was made at "x".


SERIES MOTOR CURVES
CURRENT-TORQUE
SPEED-TORQUE
SPEED-CURRENT
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6

Shunt Motor Tests.

Volts.	Amps.	Speed.	Pull.	Torque.	B.H.P.	E.H.P.	Com. Eff.	True Eff.
114	12	1070	.75	3.93	.80	1.33	43.6	22.7
114	14	1020	1.00	5.25	1.01	2.14	47.2	44.1
114	18	1016	1.25	6.56	1.27	2.75	46.2	46.1
114	22	1015	2.00	10.50	2.02	3.37	60.1	59.8
114	25	1014	3.00	18.75	3.03	3.83	79.7	75.4
114	33	1010	4.25	22.31	4.28	5.04	84.9	75.2
114	40	1009	4.50	23.62	4.58	6.11	74.9	65.0
114	50	1006	6.00	31.50	6.03	7.65	79.2	74.8
114	55	1004	7.00	36.75	7.02	8.40	83.5	75.1
114	67	1002	8.50	44.62	8.50	10.20	83.3	74.8
114	76	996	9.00	47.25	8.95	11.60	77.1	68.3
114	82	990	10.00	52.50	9.89	12.50	79.1	60.5
114	92	980	11.50	60.37	11.35	14.05	80.7	71.2
114	110	885	13.50	70.87	12.07	13.27	90.9	82.2

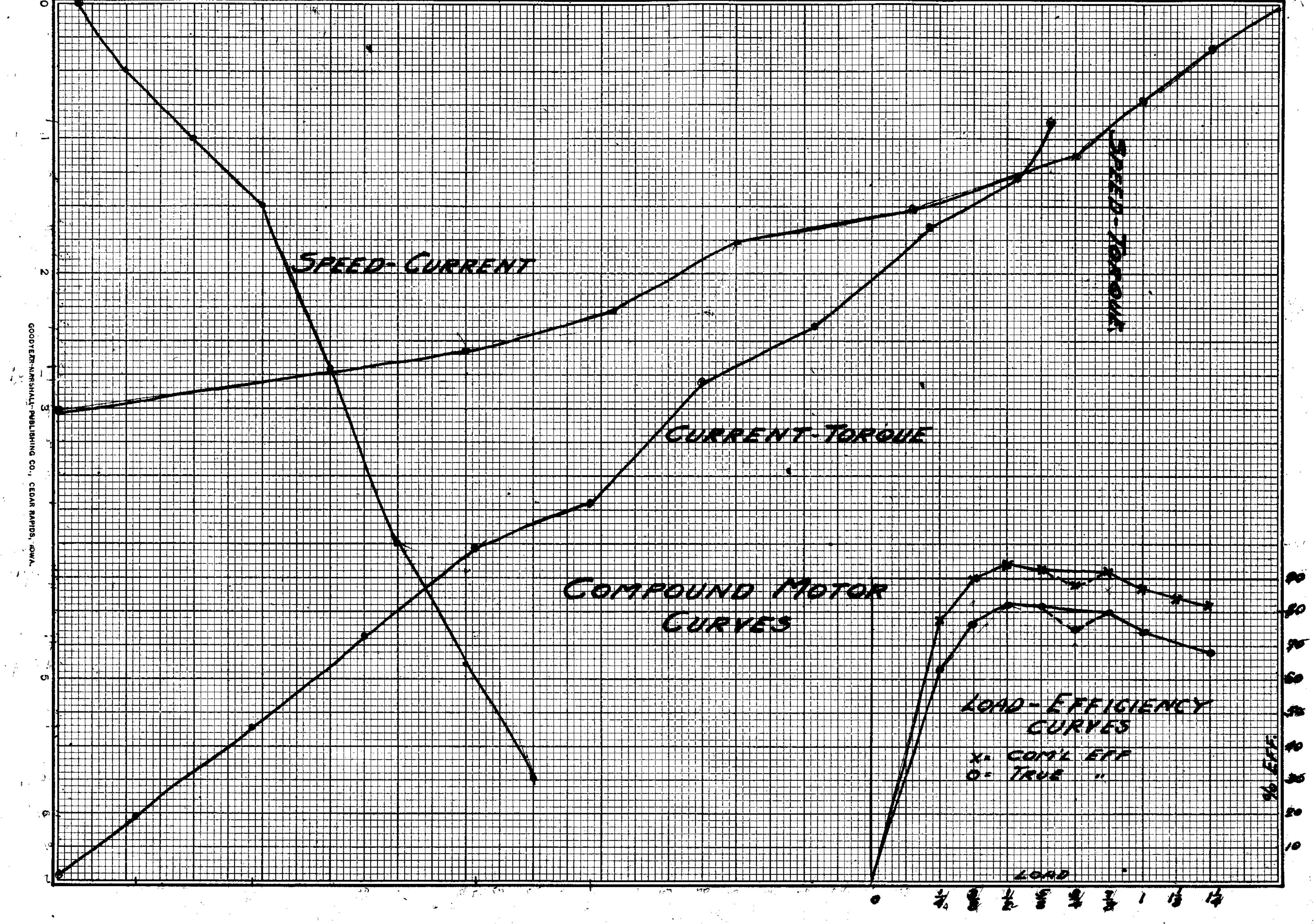
This experiment performed same as previous one.


SHUNT MOTOR CURVES
CURRENT-TORQUE
SPEED-TORQUE
SPEED-CURRENT
LOAD-EFF. CURVES
LOAD
% EFF.
0
1
2
3
4
5
6
7
8
9

Compound Motor Tests.

Volts.	Amperes.	Speed.	Pull.	Torque.	B.H.P.	E.H.P.	Com. Eff.	True Eff.
116	13	1140	1.25	6.56	1.42	2.02	70	43.0
116	20	1160	2.25	11.80	2.53	3.10	81	62.2
116	30	1120	3.75	19.68	4.17	4.60	90	76.1
116	40	1100	5.25	27.61	5.86	6.20	94	81.9
116	50	1076	6.75	35.83	7.25	7.80	93	82.7
116	60	1050	7.75	40.68	8.12	9.30	88	75.2
116	70	1033	9.75	51.18	10.00	10.80	92	80.1
116	80	1010	10.75	56.43	10.80	12.40	87	74.0
116	90	950	12.25	65.62	11.80	13.90	84	71.1
116	98	940	13.25	69.56	12.50	15.20	82	67.8
114	101	920	14.25	74.81	13.09	15.40	85	70.0

This experiment performed in the same manner as the previous ones.



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Extra Laboratory Work:

Under this heading various kinds of work is given that was done throught the year.

Part of this work was accomplished during the time for Laboratory work and others outside of this time but all of which was necessary for the time being and for the future work of this Laboratory.

Made Drawing for and had constructed--Prony Brake.

Sketch and measurements for Sleeve for Series Motor.

Ordered Proney Brake Pulley

Calibrated Board Instruments with Portable Weston Instruments.

Traced windings and connections of and from machines.

Procured Tank for Proney Brake Tests.

Ground and filed Plates for Rheostat.

Field Connections for Shunt Machine.

Field Connections for Compound Machine.

New Gasket for Engine.